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(54) NONWOVEN FABRIC FOR PLEATED FILTER AND PROCESS FOR PREPARING THE SAME

(57) An embodiment of the present invention is a nonwoven fabric for pleated filters comprising a sheath-core conjugate filament in which the core component is made of a polymer higher in melting point and the sheath component is made of a polymer lower in melting point, wherein the surfaces of the nonwoven fabric have a plurality of compressively bonded portions dotted by embossing, and the weight per unit area X (g/m^2) of the nonwoven fabric and the stiffness Y (mgf) obtained according to the Gurley method of JIS L 1096 satisfy the following formulae:

$$Y/X^2 \geq 0.03$$

$$X \geq 120$$

Another embodiment of the present invention is a filter element which uses said nonwoven fabric for pleated filters as a filter medium.

The nonwoven fabric for pleated filters of the present invention can be produced by sucking and drawing continuous filaments spun from a sheath-core conjugate spinneret, opening them, stacking them on a travelling net, to form a continuous filament web, preliminarily compressively bonding the web by a pair of heated flat rolls, and then partially thermally compressively bonding it by a pair of embossing rolls.

The present invention can provide an excellent high performance nonwoven fabric for pleated filters free from delamination, moderate in stiffness, and good in pleatability and dimensional stability.

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Description

Technical field

The present invention relates to a nonwoven fabric for pleated filters, partially compressively bonded by embossing and having a high weight per unit area, and a process for its production.

Background art

It is generally known that a nonwoven fabric composed of continuous filaments can be produced by drawing the continuous filaments spun from a spinneret by an air sucker, etc. at a high speed, letting them collide with a divergence plate mainly made of a lead, to be electrified and opened, catching them on a net conveyer, and partially thermally compressively bonding by a pair of heated embossing rolls, to form a nonwoven fabric, or by mechanically entangling the web piled and caught on a net, by needle punching, to form a nonwoven fabric. Such nonwoven fabrics are widely used as industrial materials, geotextiles, etc.

Especially for filters, since the nonwoven fabrics have high performance and are excellent in durability and workability, they are expected to be in great demand, as a substitute for the conventional filter paper. For filters, since any partial defect greatly affects the performance of filters, the nonwoven fabric used for them are required to have high quality, being less uneven in the weight per unit area and free from partial delamination in the sheet.

Japanese Patent Publication (Kokoku) No. 60-4298 discloses a nonwoven fabric producing process, in which a web composed of continuous filaments of two or more kinds different in melting point is thermally compressively bonded, to melt the filaments lower in melting point, for production of a nonwoven fabric.

However, the nonwoven fabric is insufficient in thermal compressive bonding in the thickness direction even if thermal compressive bonding is effected by a pair of embossing rolls, and delamination is liable to occur at the center of the thickness. Furthermore, since the thermal compressive bonding must be effected at a temperature higher than the melting point of the filaments lower in melting point, the filaments lower in melting point are liable to adhere to the surfaces of the embossing rolls, and this contamination causes the embossed sheet to be attracted by the rolls, thus disadvantageously partially delaminating the surfaces of the nonwoven fabric. Therefore, if the nonwoven fabric is pleated for use as a filter, it cannot be well pleated, and at the partially delaminated portions, fine particles leak. Furthermore, on the partially delaminated surface, a nap is raised, making it difficult to allow dust to be released, lowering the filter performance. Because of these problems, the nonwoven fabric is inefficient as a filter medium.

Japanese Laid-open Patent Application (Kokai) Nos. 2-133644, 2-169756 and 3-8856 disclose nonwoven fabrics composed of sheath-core conjugate filaments respectively consisting of a polymer higher in melting point used as the core component and a polymer lower in melting point used as the sheath component.

The nonwoven fabric disclosed in Japanese Laid-open Patent Application (Kokai) No. 2-133644 has a web thermally compressively bonded on the entire surface, and has smoothness and performance like a film. The weight per unit area specified here is 40 g/m^2 at the highest.

Japanese Laid-open Patent Application (Kokai) No. 2-169756 intends to provide a nonwoven fabric having non-melting-non-bonded portions kept bulky to give a soft fabric feeling, for providing excellent surface abrasion resistance and strength. The weight per unit area specified here is 40 g/m^2 at the highest.

Japanese Laid-open Patent Application (Kokai) No. 3-8856 discloses a nonwoven fabric used as a mat in asphalt road construction, waterproof material and soundproof material. The weight per unit area specified here is 100 g/m^2 at the highest.

On the other hand, nonwoven fabrics exceeding 100 g/m^2 in weight per unit area are disclosed in Japanese Laid-open Patent Application (Kokai) Nos. 3-137261 and 3-146757, but they are impregnated with asphalt or acrylic resin, to be used for roofing.

The object of the present invention is to provide a filter medium excellent in pleatability, free from sheet delamination and high in collection efficiency.

Disclosure of the invention

An embodiment of the present invention is a nonwoven fabric for pleated filters comprising a sheath-core conjugate filaments in which the core component is made of a polymer higher in melting point and the sheath component is made of a polymer lower in melting point, wherein the surfaces of the nonwoven fabric have a plurality of compressively bonded portions dotted by embossing, and the weight per unit area X (g/m^2) of the nonwoven fabric and the stiffness Y (mgf) obtained according to the Gurley method of JIS L 1096 satisfy the following formulae:

$$Y/X^2 \geq 0.03$$

$$X \geq 120$$

Another embodiment of the present invention is a filter element which uses said nonwoven fabric for pleated filters, as a filter medium.

The present invention can provide an excellent high performance nonwoven fabric for pleated filters, free from delamination, moderate in stiffness, and good in pleatability and dimensional stability.

An embodiment of the production process of the present invention is a process for producing a nonwoven fabric for pleated filters, comprising the steps of sucking and drawing continuous filaments spun from a sheath-core conjugate spinneret opening them, stacking them on a travelling net, to form a continuous filament web, preliminarily compressively bonding the web by a pair of heated flat rolls, and then partially thermally compressively bonding it by a pair of embossing rolls, to form a nonwoven fabric of 120 g/m^2 or more in weight per unit area.

According to the production process of this embodiment, a high performance nonwoven fabric for pleated filters can be produced in one series of steps.

Best Mode for Carrying out the invention

One embodiment of the present invention is a nonwoven fabric for pleated filters, in which the weight per unit area X (g/m^2) is 120 or more and the weight per unit area X and stiffness Y (mgf) satisfy the following formulae.

$$Y/X^2 \geq 0.03$$

$$X \geq 120$$

The stiffness referred in this specification is measured according to the Gurley method of JIS L 1096, using a sample of 1 inch in the transverse direction and 1.5 inches in the machine direction.

In the nonwoven fabric of the present invention, it is important that the value of Y/X^2 is 0.03 or more. If the value of Y/X^2 is less than 0.03, the nonwoven fabric is insufficient in stiffness, hence does not have sharp or uniform folds of the pleats and is poor in pleatability, and it also becomes difficult to install the pleated nonwoven fabric into the filter unit. The value of Y/X^2 is preferably 0.036 or more.

The nonwoven fabric comprises sheath-core conjugate filaments comprising two components; a polymer higher in melting point and a polymer lower in melting point.

In the case of a conventional nonwoven fabric composed of a mixed filament which has one filament component higher in melting point and another filament component lower in melting point, even if the temperature and pressure of the embossing rolls are raised, the relation between the weight per unit area (X) and stiffness (Y) of the nonwoven fabric cannot satisfy $Y/X^2 \geq 0.03$. As a result, the bonding strength becomes insufficient to cause delamination, thus lowering the filter performance, pleatability, etc. If the nonwoven fabric is impregnated with a resin such as an acrylic resin to compensate for the bonding strength of filaments, the porosity of the filaments constituting the nonwoven fabric is decreased, to significantly increase, disadvantageously, the initial pressure drop of the filter.

The structure of the sheath-core conjugate filament is most preferably concentric, but can also be of an eccentric or odd-shaped type. It also can be concentric with triple or higher multiple circles with an intermediate layer(s) provided between the core and the sheath.
core and the sheath.

The polymer higher in melting point and the polymer lower in melting point used for the filaments include polyesters, nylon, polypropylene, their copolymers, and these polymers containing any other polymer and additives.

As the polymer used as the core component, polyethylene terephthalate is preferable having regard to the strength and heat resistance of the nonwoven fabric. As the polymer lower in melting point used as the sheath component, a copolymerized polyester with a melting point lower than that of the core component by 20°C or more is preferable having regard to adhesive strength.

The sheath component preferably accounts for 5 to 40 wt% of the sheath-core continuous filament, having regard to sufficient covering of the core component and stiffness.

If antistatic property is required, it is preferable that the core component contains electrically conductive particles. The material of the conductive particles can be selected from carbon black, metal compounds, metal oxides, etc. Having regard to fiber formability, carbon black is preferable. In this case, the frictionally electrified quantity of the nonwoven fabric measured according to the method C of JIS L 1094 is preferably less than 10 μC/m^2, more preferably less than 5 μC/m^2. The conductive particle content is preferably 2 wt% or more based on the weight of the filament having regard to pleatability and higher antistatic property.

The fiber fineness of the filaments constituting the nonwoven fabric is preferably 1 denier or more, considering the spinning stability and productivity, and on the other hand, preferably 10 deniers or less having regard to higher filtration

efficiency.

The surfaces of the nonwoven fabric of the present invention have a plurality of compressively bonded portions. The compressively bonded portions are formed as dents by embossing the surfaces of the nonwoven fabric, and at the compressively bonded portions, filaments constituting the nonwoven fabric are melting-bonded by heat and pressure. In other words, dotted portions in which filaments are melting-bonded and densely gathered together as compared with the other portions exist on the surfaces of the nonwoven fabric.

In order to make compressively bonded portions dotted on the surfaces of a nonwoven fabric, usually a pair of heated embossing rolls are used. In the present invention, the style, combination, etc. of the embossing rolls are not especially limited. However, it is preferable that the engraved depth of the embossing rolls is about 0.5 to 1 mm, to achieve $Y/X^2 \geq 0.03$ in the relation between the weight per unit area X and stiffness Y of the nonwoven fabric, and to form dents with an average depth of 60 µm or less.

The average depth of dents is 60 µm or less as the average roughness (Ra) obtained according to JIS B 0601. For example, a surface roughness tester, SE-40C (in conformity with JIS B 0651 "Instruments for Measurement of Surface Roughness by the Stylus Method") produced by K.K. Kosaka Kenkyujo generally used for measuring the surface roughnesses of metals, etc. can be used.

If the average depth of dents is 60 µm or less, the nap of the filter medium can be considerably inhibited as compared with conventional nonwoven fabrics. If the average depth of dents exceeds 60 µm, the nap of the nonwoven fabric grows like a geometric series, making the nonwoven fabric unsuitable as a filter medium. If the average depth of dents is small, the surface roughness of the nonwoven fabric is small, and the abrasion resistance between dust or the filter support such as a wire gauze and the filter medium can be significantly decreased. Therefore, the nap of the filter medium can be inhibited, and the dust entangled with the nap can be decreased to improve the dust removal ability after pulse jetting, hence extending the bag life.

The ratio of the compressively bonded portions in the entire area of the nonwoven fabric is preferably smaller, though not especially limited, say, preferably 5 to 35%, more preferably 10 to 30%. To specify the quantity, if the area of each compressively bonded portion is 0.5 to 1.5 mm^2, the number of the compressively bonded portions existing on the surfaces of the nonwoven fabric is preferably 10 to 50 per square centimeter, more preferably 25 to 35 per square centimeter. The form of the dents is not especially limited, but any form which can be dotted such as rectangle, parallelogram, circle, or ellipse, etc. is preferable.

The compressively bonded portions referred in this specification mean the portions in which the fibers are compressively bonded and densely gathered together by the protrusions of the embossing rolls. For example, when a pair of a top roll and a bottom roll respectively with a plurality of straight grooves formed parallel to each other on the surfaces, with the grooves of the top roll and the grooves of the bottom roll crossed at a certain angle, are used as the embossing rolls, the compressively bonding portions mean the portions in which the fibers of the nonwoven fabric are compressively bonded and densely gathered together between the protrusions of the top roll and the protrusions of the bottom roll. In this case, the portions pressed between the cavities of the top roll and the protrusions of the bottom roll, and between the protrusions of the top roll and the cavities of the bottom roll are not called the compressively bonded portions. When the top or bottom roll only has a predetermined pattern of cavities and protrusions while the other roll is flat without any cavities or protrusions, the compressively bonded portions mean the portions in which the fibers of the nonwoven fabric are compressively bonded and densely gathered together between the protrusions of the roll with protrusions and cavities and the flat roll.

The apparent density of the compressively bonded portions is preferably 0.6 g/cm^3 or more having regard to better bonding. The apparent density of the non-compressively bonding portions is preferably less than 0.6 g/cm^3 to let the filaments exist independently for preventing the nonwoven fabric from being formed like a film and for achieving the intended filter performance.

The nonwoven fabric for pleated filters of the present invention is characteristically excellent in pleatability and dimensional stability while the high filter performance Is kept, even though the nonwoven fabric is as high as 120 g/m^2 or more in weight per unit area, and such excellent features could not be obtained with the conventional nonwoven fabrics. Furthermore, the effect of the present invention can be exhibited even if the weight per unit area is 150 g/m^2 or more, or 200 g/m^2 or more. The effect of the present invention can be remarkably exhibited rather when the nonwoven fabric is as high as 200 g/m^2 in weight per unit area, since the conventional nonwoven fabrics are generally poor in pleatability and dimensional stability when they are high in weight per unit area.

If the nonwoven fabric for pleated filters of the present invention is used as a filter medium, a high performance filter element can be provided.

The nonwoven fabric for pleated filters of the present invention can be obtained by sucking and drawing the continuous filaments spun from a sheath-core conjugate spinneret, by such a means as an air sucker, opening the filaments, stacking them onto a travelling net, to form a continuous filament web, and thermally compressively bonding the web.

The thermal compressive bonding can be achieved by partially compressively bonding by a pair of heated embossing rolls, especially preferably by preliminarily compressively bonding by a pair of flat rolls, to enhance the apparent

density of the web, and then embossing by a pair of embossing rolls.

In the thermal compressive bonding, it is preferable to set the rolls at a temperature lower than the melting point of the component lower in melting point, by 10°C or more, to prevent the contamination of the rolls.

Examples

The present invention is described below in more detail with reference to Examples. The properties in the Examples were measured according to the following methods.

[Thickness of nonwoven fabric]

Measured according to the thickness measuring method specified in JIS L 1906.

[Weight per unit area (g/m^2)]

Measured according to the method for measuring the weight per unit area specified in JIS L 1906.

[Stiffness]

A sample of 1 inch in the transverse direction and 1.5 inches in the machine direction was taken and measured according to the Gurley method specified in JIS L 1096.

[Average depth of dents]

The average depth of dents is the arithmetic average roughness (Ra) obtained according to JIS B 0601 "Surface Roughness", using a surface roughness tester (Model SE-40C produced by K.K. Kosaka Kenkyujo in conformity with JIS B 0651 "Instruments for Measurement of Surface Roughness by the Stylus Method"). The arithmetic average roughness was obtained with a cutoff value of 2.5 mm for a length of 8 mm.

[Sheet delamination]

Samples of 20 cm in the transverse direction and 80 cm in the machine direction were taken generally in the machine direction, and bent respectively to form a circular arc of 10 cm in diameter, and the delamination was evaluated according to the following criterion:

Criterion

○ : No delamination was observed at all.
△ : One sample showed delamination of less than 2 cm.
X : Two or more samples showed delamination.

[Pleatability]

A sheet of 50 cm in width and 300 m in length was pleated at 3 cm intervals by a rotary pleating machine, and the pleatability was evaluated according to the following criterion:

Criterion

○ : The folds of pleats were sharp and uniform, and the sheet did not meander.
△ : The folds of pleats were rather uneven and the sheet slightly meandered, but not to such a degree as to be detrimental to practical use.
X : The folds of pleats were uneven and the sheet meandered, to such a degree as to render inconvenient the installation into the filter unit.

[Apparent density of compressively bonded portions (g/cm^3)]

A section of a compressively bonded portion was photographed hundred-fold using a scanning electron microscope, and the dimensions were measured using vernier calipers. From the magnification, the thickness was calcu-

lated, and the apparent density of the compressively bonded portion was calculated from the following formula:

Apparent density of an compressively bonded portion =
Weight per unit area / Thickness of the compressively bonded portion

[Apparent density of non-compressively bonded portions (g/cm^3)]

The thickness of a non-compressively bonded portion was evaluated according to JIS L 1906, and the apparent density of the non-compressively bonded portion was calculated from the following formula:

Apparent density of a non-compressively bonded portion =
Weight per unit area / Thickness of the non-compressively bonded portion

[Filter performance]

⟨Evaluation of nap⟩

Evaluated according to the Taber method specified in JIS L 1906 "Abrasion Test".

⟨Collection efficiency⟩

A sample disc of 170 mm in diameter was installed in a duct equipped with a blower, and the air in a laboratory was sucked at an air velocity of 3 m/min by the blower. The atmospheric dust in the laboratory was referred to for evaluation.

The number of particles (0.5 µm to 1 µm) in the atmospheric dust of the laboratory was counted by a particle counter (KC01B produced by Rion K.K.) (this is expressed by a in the following formula). The number of particles (0.5 µm to 1 µm) of the air in the duct which passed the nonwoven fabric was counted by said particle counter (this is expressed by b in the following formula). The collection efficiency was obtained from the following formula:

$$\text{Collection efficiency (\%)} = 100 \times (a - b)/a$$

Example 1 and Comparative example 1

Polyethylene terephthalate of 0.66 in intrinsic viscosity and 262°C in melting point, and isophthalic acid-copolymerized polyester mainly composed of ethylene terephthalate of 0.68 in intrinsic viscosity and 228°C in melting point were rendered molten by respectively different extruders, and spun from a sheath-core spinnable spinneret, with the throughput adjusted to give a filament fineness of 2 deniers and to give a ratio of the component lower in melting point of 15 wt% based on the weight of all the fibers. In succession, the spun filaments were drawn at a high speed of about 5000 m/min by an air sucker, brought into collision with a divergence plate mainly made of lead, to be opened, and subjected to a jet and caught on a travelling net conveyor, to form a nonwoven fabric web. In this case, the speed of the net conveyer was changed to obtain nonwoven fabrics of 120 g/m^2 (0.40 mm thick), 200 g/m^2 (0.55 mm thick), 260 g/m^2 (0.61 mm thick), and 360 g/m^2 (0.75 mm thick) respectively in weight per unit area. Each of the nonwoven fabrics was preliminarily compressively bonded by flat rolls of 130°C in temperature and 50 kg/cm in pressure, and then thermally compressively bonded by a pair of a top embossing roll and a bottom embossing roll respectively with a plurality of straight grooves (0.8 mm in engraved depth) formed in parallel to each other on the surface, at a temperature of 220°C with a bonding pressure of the embossing rolls changed as shown in Table 1. The compressively bonded portions were parallelograms of 0.6 mm^2 in area, and the number of compressively bonded portions was 25 per square centimeter. The total area of the compressively bonded portions accounted for 15%. In succession, the embossed sheet was cut to be 50 cm in width, and pleated by a rotary pleating machine. The results are shown in Table 1.

As can be seen from Table 1, the nonwoven fabrics of Example 1 did not cause sheet delamination and were good in pleatability, dimensional stability, etc., being satisfactory as filter media. Furthermore, since the values of Y/X^2 are generally 0.036 or more, it can be seen that the nonwoven fabrics are stable in delamination resistance and pleatability.

Example 2

Thermally compressively bonding was effected as done in Example 1, except that the nonwoven fabric was 220 g/m^2 in weight per unit area, that the bonding pressure was 60 kg/cm, and that the embossing rolls used was 5%

(Example 2-(1)), 10% (Example 2-(2)), 15% (Example 2-(3)), 20% (Example 2-(4)), 30% (Example 2-(5)), or 40% (Example 2-(6)) in the total area of compressively bonded portions.

The stiffness values of Example 2-(1)~(6) were respectively 1580 mg, 2030 mg, 2010 mg, 1780 mg, 1630 mg, and 1490 mg, and the values of Y/X^2 were 0.033, 0.041, 0.041, 0.037, 0.033, and 0.031.

The nonwoven fabrics were cut to be 50 cm in width, and pleated by a rotary pleating machine.

The pleated filters obtained from the nonwoven fabrics of 5 to 30% in the total area of compressively bonded portions in Example 2-(1)~(5) were as good as Grade 4 or higher in the evaluation of nap, and excellent in delamination resistance and pleatability. The nonwoven fabric of 40% in the total area of compressively bonded portions in Example 2-(6) was Grade 4 or higher in the evaluation of nap and excellent in delamination resistance, but rather uneven in the folds of pleats and slightly meandering, even though there was no problem in practical use.

Example 3

Nonwoven fabrics of 200 g/m^2 in weight per unit area were produced as described for Example 1, except that the fiber fineness of the filaments was 2 deniers and that the ratio of the component lower in melting point to the total weight of all the fibers was 30 wt% (Example 3-(1)), 20 wt% (Example 3-(2)), 10 wt% (Example 3-(3)), or 5 wt% (Example 3-(4)). In succession, they were thermally compressively bonded as described for Example 1, except that the temperature of the embossing rolls was 200°C and that the bonding pressure was 60 kg/cm.

The stiffness values of Example 3-(1)~(4) were respectively 1380 mg, 1620 mg, 1410 mg, and 1250 mg, and the values of Y/X^2 were 0.035, 0.040, 0.035, and 0.031.

The nonwoven fabrics were in succession cut to be 50 cm in width, and pleated by a rotary pleating machine.

The pleated nonwoven fabrics were good as pleated filters without causing delamination.

Comparative example 2

Polyethylene terephthalate of 0.66 in intrinsic viscosity and 262°C in melting point and isophthalic acid-copolymerized polyester mainly composed of ethylene terephthalate of 0.68 in intrinsic viscosity and 228°C in melting point were melt-spun respectively separately at a ratio of 80 : 20, drawn at a high speed of about 5000 m/min by an air sucker, brought into collision with a divergence plate mainly made of lead, to be opened, and subjected to a jet and caught on a travelling net conveyer, to form a nonwoven fabric web composed of mixed filaments.

Then, the web was preliminarily compressively bonded by flat rolls of 130°C in temperature and 50 kg/cm in pressure, and thermally compressively bonded using the same embossing rolls as used in Example 1 at a bonding pressure of 60 kg/cm^2 at a temperature of 220°C (Comparative Example 2-(1)) or 240°C (Comparative Example 2-(2)), to obtain two nonwoven fabrics of 260 g/m^2 in weight per unit area different in thermal embossing temperature.

The nonwoven fabric obtained at an embossing temperature of 220°C (Comparative Example 2-(1)) was insufficient in thermal compressive bonding strength, and delamination occurred at the center of the thickness.

In the nonwoven fabric obtained at an embossing temperature of 240°C (Comparative Example 2-(2)), sheet surface delamination due to contamination on the surfaces of embossing rolls occurred, and the nap was evaluated as Grade 2. So, the nonwoven fabric was unsuitable as pleated filters.

Example 4

Polyethylene terephthalate of 260°C in melting point containing carbon black as electrically conductive particles in an amount of 2 wt% (Example 4-(1)), 3 wt% (Example 4-(2)), or 4 wt% (Example 4-(3)) based on the weight of the conjugate filaments of sheath-core structure was used as the core component, and isophthalic acid-copolymerized polyester mainly composed of ethylene terephthalate of 230°C in melting point was used as the sheath component. Sheath-core conjugate filaments consisting of the core component and the sheath component at a ratio by weight of 85 : 15 were melt-spun to be 2 deniers in fiber fineness, drawn at a high speed of about 4000 m/min by an air sucker, opened by air pressure, and stacked on a travelling net. The web was thermally compressively bonded as described for Example 1, except that the temperature of the embossing rolls was 200°C and that the bonding pressure was 60 kg/cm, to obtain a nonwoven fabric of 200 g/m^2 in weight per unit area and 0.54 mm in thickness.

The nonwoven fabrics of Example 4-(1), 4-(2) and 4-(3) were respectively 7 μC/m^2, 6 μC/m^2 and 4 μC/m^2 in frictionally electrified quantity, 2500 mg, 2700 mg and 2900 mg in stiffness, and 0.063, 0.068 and 0.073 in Y/X^2. They were also good in filter performance, and had stiffness enough to withstand pleating.

Industrial applicability

The present invention can provide an excellent high performance nonwoven fabric for pleated filters free from dela-

mination, moderate in stiffness, and good in pleatability and dimensional stability.

Furthermore, the present invention can provide a high performance filter element using said nonwoven fabric for pleated filters.

Table 1

	Bonding pressure (kg/cm)	Weight per unit area (g/m^2)	Stiffness (mg)	Y/X^2	Average depth of dents (µm)	Sheet delamination	Pleatability
Comparative example 1-(1)	40	120	400	0.027	33	○	×
Example 1-(1)	50		480	0.033	35	○	△
1-(2)	60		530	0.037	37	○	○
1-(3)	70		560	0.039	40	○	○
Comparative example 1-(2)	40	200	1130	0.028	34	×	×
Example 1-(4)	50		1250	0.031	39	△	△
1-(5)	60		1580	0.040	43	○	○
1-(6)	70		1750	0.044	45	○	○
Comparative example 1-(3)	40	260	1920	0.028	35	×	△
Example 1-(7)	50		2390	0.035	40	△	△
1-(8)	60		2530	0.037	48	○	○
1-(9)	70		2850	0.042	58	○	○
Comparative example 1-(4)	40	360	3600	0.028	50	×	△
Example 1-(10)	50		4180	0.032	53	△	△
1-(11)	60		4620	0.036	55	○	○
1-(12)	70		4950	0.038	65	○	○

Apparent density of compressively bonding portions (g/cm^3)	Apparent density of non-compressively bonding portions (g/cm^3)	Filter performance		
		Nap (Grade)	Collection efficiency (%)	Pressure drop (mmAq)
0.46	0.3	3	21	1.7
0.62	0.3	4	23	1.7
0.71	0.3	5	24	1.7
0.9	0.3	5	24	1.8
0.52	0.36	3	45	2.7
0.61	0.36	4	47	3.0
0.7	0.36	5	49	3.2
1.1	0.36	5	52	3.4
0.59	0.43	3	51	3.9
0.76	0.43	4	56	4.0
0.91	0.43	5	52	4.2
1.22	0.43	4	55	4.4
0.66	0.48	3	45	7.0
0.87	0.48	4	55	7.5
1.0	0.48	5	60	8.5
1.26	0.48	3	63	9.0

Claims

1. A nonwoven fabric for pleated filters comprising sheath-core conjugate filaments in which the core component is made of a polymer higher in melting point and the sheath component is made of a polymer lower in melting point, wherein the surfaces of the nonwoven fabric have a plurality of compressively bonded portions dotted by embossing, and the weight per unit area X (g/m^2) of the nonwoven fabric and the stiffness Y (mgf) obtained according to the Gurley method of JIS L 1096 satisfy the following formulae:

$$Y/X^2 \geq 0.03$$

$$X \geq 120$$

2. A nonwoven fabric for pleated filters, according to claim 1, wherein the average depth of the dents formed as the compressively bonded portions measured according to JIS B 0601 is 60 μm or less.

3. A nonwoven fabric for pleated filters, according to claim 1, wherein the apparent density of the compressively bonded portions is 0.6 g/cm^3 or more and the apparent density of the non-compressively bonded portions is less than 0.6 g/cm^3.

4. A nonwoven fabric for pleated filters, according to claim 1, wherein the total area of the compressively bonded portions accounts for 5 to 35% of the entire area of the nonwoven fabric.

5. A nonwoven fabric for pleated filters, according to claim 1, wherein the core component is polyethylene terephthalate, and the sheath component is a copolymerized polyester with a melting point lower than that of the core component by 20°C or more.

6. A nonwoven fabric for pleated filters, according to claim 1, wherein the sheath component accounts for 5 to 40 wt% of the sheath-core continuous filaments.

7. A nonwoven fabric for pleated filters, according to claim 1, wherein the fiber fineness of the sheath-core continuous filaments is 1 to 10 deniers.

8. A nonwoven fabric for pleated filters, according to claim 1, wherein the core component contains electrically conductive particles.

9. A nonwoven fabric for pleated filters, according to claim 8, wherein the electrically conductive particles are carbon black.

10. A nonwoven fabric for pleated filters, according to claim 8 or 9, wherein the frictionally electrified quantity of the nonwoven fabric measured according to the method C of JIS L 1094 is less than 10 $\mu C/m^2$.

11. A filter element, comprising the use of the nonwoven fabric for pleated filters stated in any one of claims 1 to 10, as a filter medium.

12. A process for producing a nonwoven fabric for pleated filters comprising the steps of: sucking and drawing continuous filaments spun from a sheath-core conjugate spinneret, opening them, stacking them on a travelling net, to form a continuous filament web, preliminarily compressively bonding the web by a pair of heated flat rolls, and partially thermally compressively bonding it by a pair of embossing rolls, to form a nonwoven fabric of 120 g/m^2 or more in weight per unit area.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP96/00863

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 D04H3/14

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^6 D04H3/14, D04H1/54

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP, 57-47958, A (Asahi Chemical Industry Co., Ltd.), March 19, 1982 (19. 03. 82)(Family: none)	1 - 7 8-10, 11
Y	JP, 62-162058, A (Siebe Gorman & Co., Ltd.), July 17, 1987 (17. 07. 87) & EP, 230097, A & US, 4726978, A	8-10, 11
Y	JP, 02-264018, A (Petoka K.K.), October 26, 1990 (26. 10. 90)(Family: none)	11

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
June 25, 1996 (25. 06. 96)	July 16, 1996 (16. 07. 96)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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